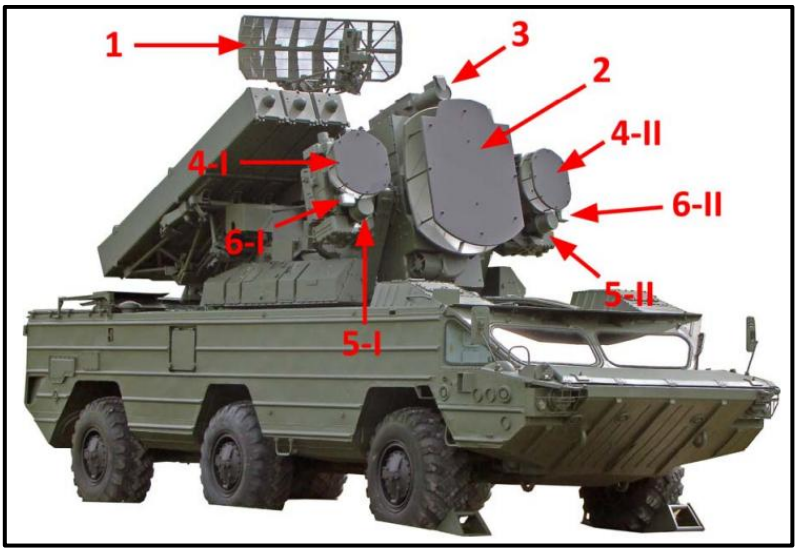
9K33 Osa (SA-8 Gecko)

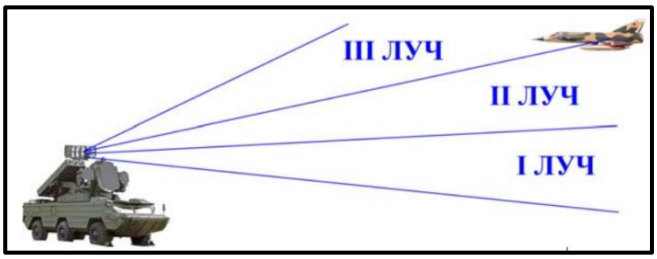
The 9K33 Osa was designed with one of the most complicated mechanically scanning radar system ever. It is similar to 2K12 Krug (SA-4) but despite its smaller engagement range it was even more complex in some aspects comparing to the SA-4. (Krug was developed before the Osa but because of the structure of full publication the Osa is explained first because it was on lower level in air defense organization. Osa was on divisional level SAM system while Krug was on army or even on front level.)

The 2K12 had one target and one fire channel while the Osa was able to guide two missiles on a single target (one target and two missile channels) thanks to the double amount of antennas for each functions. The 9K33 Osa system has the following antennas see on the image below:



Main parts of the Osa-AKM variant.

1. СОЦ, (SOC) – Target Acquisition Radar (4 cm wavelength)
2. ССЦ, (SSC) – Narrow beam Monopulse Target/Missile Tracking Radar
3. ТОВ, (TOV) – Target Tracking Camera
4. Medium beam Monopulse Missile Tracking Radar for channels–I/II
5. Conical Scanning Wide beam Missile Tracking Radar for channels–I/II
6. Wide beam Missile Interrogator Radar for channels–I/II



With the target acquisition radar of the vehicle the Osa is able to search targets autonomously up to 45 km distance. (Against smaller target the detection distance is smaller.) The radar is able to measure (estimate) the altitude of the target thanks to shape of the beams of the radar. It can be determined the presence of the target in each beams/lobes but this measuring does not provide exact altitude information. Similar to Dvina/Volkhov and Neva systems (SA-2/3 families) this is enough precise to find and lock on target with elevation scanning to a certain azimuth direction.

(The 1S11 radar of the 2K12 Kub system is also able to perform such altitude estimation but the target acquisition radar has only two lobes.)

The Osa similar to S-75/125 (SA-2/3) and 2K11 (SA-4) uses radio command guidance but it's working principle is different from any of predecessor system. The Osa got the later developed monopulse antenna technology for target tracking. Comparing to Volkhov uses both narrow and wide beam antennas either which has impact on the usable jamming methods – thanks to the monopulse antenna is immune to angle deception jamming – as well as on SEAD activity with anti-radiations missiles. Until the arrival of the AGM-88 HARM in mid '80d the Osa had a very good almost ARM resistant capability against AGM-45 Shrike.

In normal cases as long as possible the target is tracked optically with the TOV camera. Finding the target optimally is supported by higher level IADS elements of the army air defense (see later) using the SOC radar is not necessary as long as other higher level target acquisition radars can provide target data via radio or digital data link. By using the TOV the Osa can operate without any radar emission until the launch of the first missile. The working principle of the guidance and radar system is the following:

- After the upwards launch of the missile (to avoid blinding the Karat camera with missile smoke) the wide beam antenna (white boxy '6' on the image above) starts emitting missile guidance signals. The mechanically rotating receiver (round green '5' labelled antenna) receives signals from the missile and aims the whole gyro-stabilized platform (4-5-6 antenna group) towards the missile within 0.8 seconds after launch.

- After missile capture (0.8 seconds of the launch) the medium beam mono-pulse antenna ('4' labelled) is tracking the missile and guiding it to the beam of the narrow beam target tracker antenna ('2' labelled).

- When the missile signal is captured by the target tracking mono-pulse narrow beam antenna ('2' labelled) its guidance is continuing using it and antenna 4-5-6 is resets itself.

In short all of smaller extra antennas comparing to 2K11 Krug are designed to guide the missile eventually the single main lobe ('2' labelled) of the system which was the operation principle of the Dvina and Volkhov systems during the whole guidance.

The Osa is able to perform only three point guidance[1] which is the worst solution against maneuvering targets. This design aspect was the result and direct consequence the experiences of Vietnam. In late 1967 only 4% of the Dvina guidance was possible with automatized tracking. In rest of cases because of electronic jamming targets manually had to be tracked which forced Dvina batteries to three point guidance.

To override the limits of guidance the missile was designed with 25G maximal turning capability (M2 and M3 missile subvariants) as long as the engine is running. The maneuvering capability was designed accordingly to demand of the very specific guidance. In the mid '70s such capability was considered way above every other similar size missile. Even against the upcoming 4th generation fighters was suitable the performance of the missile. Against older fighters and attack planes such as F-4 Phantom II, A-4 Skyhawk or A-6 Intruder with subsonic speed and with much less maneuverability performance the Osa meant even higher threat.

[1] https://www.youtube.com/watch?v=DnsIy4Pselo *The missile perform quite hard turn in the terminal phase even the target is almost non moving.*

The 9M33M2 (as well as M3) missile has dual thrust rocket engine (similar to US AIM-7F and AIM-7M) what ensures very good kinematic range considering the size and weight of missile. According the field manual the maximal engagement range of the Osa-AKM is 10.3 km up to 5 km altitude. Greek operators during field live fire training experienced this is a pessimistic value. Beyond this nominal engagement distance the missile has enough kinetic energy reserve to perform hard turn.

Depending on atmospheric temperature the burn time of the rocket engine is 13-19 seconds (in 20 ^{O}C is about 16 seconds) burnout speed is about 640 m/s. Judging by these values the missile can fly about 8-9 km until engine burnout therefore deceleration at 10.3 km has only slight impact on missile maneuverability.

The launch weight of 9M33M2 is 126 kg, warhead weight is 14.3 kg readiness time is 15 seconds (because of gyroscope spooling up process).

Engagement limitations of with the 9M33M2 missile are the followings:

- Target speed 300 m/s (Mach 1.0) 25-5000 m altitude, 10.3 km range
- Target speed 500 m/s (Mach 1.6) 100-5000 m altitude, 10.3 km range

Engagement limitations of with the 9M33M3 missile are the followings:

- Target speed 100 m/s (360 km/h) 10-25 m altitude, 6.5 km range
- Target speed 300 m/s (Mach 1.0) 25-5000 m altitude, 10.3km range
- Target speed 500 m/s (Mach 1.6) 100-5000 m altitude, 10.3 km range

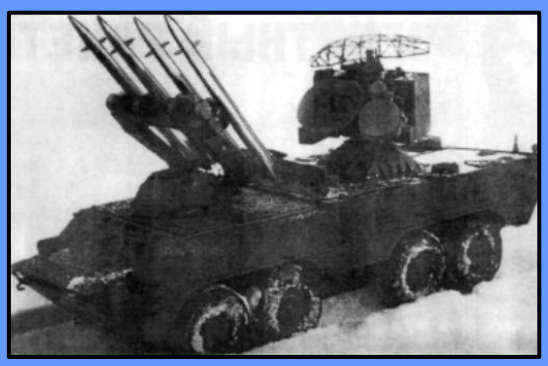
With the more advanced 9M33M3 missile it is possible engage hovering targets down to 0 m altitude. The range of the missile surpasses the range of the BGM-71 TOW guided missiles which in the era of Osa was the longest range anti-tank guided missile on helicopters. The Osa means still a considerable threat even for the decade later developed AH-64A which has 8 km maximal engagement range with the AGM-114 Hellfire missile.

The first (initial) variant of the SA-8 was able to carry 4 missiles (see on the left) which were stored on rails as was typical for every contemporary SAM system regardless we are talking PVO or army air defense. For the later upgraded AK and AKM variants the carried missile capacity was increased to 6. Besides the quantity boost it was introduced a new kind of storage for the missiles they were stored in container/canisters instead on placing them on rails.

Similar to Strela-1/10 systems the Osa is amphibious but using the weaponry is not possible on water. For missile launch the vehicle has to stop and has to be on land. After stopping the vehicle the ready to launch state is achievable within 30 seconds. The tower can be turned ±330 degrees which means full rotation cannot be performed but it is possible to launch missile to any direction. This lack of rotation capability has to be considered during the engagement against close flying targets which flies nearby the system to stay within the turning limitations of the tower.

The birth of the Osa system was not an easy process. Because of the long and delayed development and production this was the “black sheep” among the Soviet SAMs. When became available for NSWP countries and other 3rd World Soviet friendly countries many of them had to acquire the expensive 2K12 Kub (SA-6 Gainful) regiments for their best motorized divisions which meant a serious burden for the economy of the Eastern Bloc countries. (Normally only tank division got the Kub regiment on divisional level.)

The development of the predecessor system started in 1959 it was called Ellipse (see below). Among the design requirements was the 8 km maximal engagement range up to Mach 1 target speed between 50-5000 meter altitude. They system was designed for both army air defense with launch during march capability and naval air defense on ships.



The work started in NII-20 design bureau under the leadership of MM Kosichkin who had extensive experience in the development of small-sized mobile artillery radar systems. In 1967 the Ellipse was rejected because it was unable to launch full 360 degree azimuth , unable to effectively engage targets below 100 m, unable to engage suddenly appearing targets and finally the buoyancy of the vehicle was insufficient. During of the trials one of the vehicle simply sunk.

Following the unsuccessful trial MM Kosichkin (above left) was replaced by V.P. Efremov (above right) he was appointed to lead NII-20 bureau. He proposed to delete the requirement of launch capability on the move however, suggested to keep the ability of detecting targets during march, and offered a second missile channel. After a heated discussion of his proposals and despite several protests during the meeting Chief Marshal of Artillery PN Kuleshov agreed to the design changes. The base vehicle (Object 1040) was replaced with the BAZ-5937 chassis to increase buoyancy. To reduce its weight and increase its azimuth coverage, the separate launcher and radar towers were rearranged into a single unit.

After the successful state trials in October 4th 1971 the 9K33 OSA (SA-8A Gecko) was adopted with capability of killing a single target with two 9M33M missiles. Production: In ’70-1, ’71-3, ’72-15. In 1973 the 1st regiment was formed with 12 vehicles (a full regiment consists 20 vehicles therefore it was not a full unit) .

The initial series had the following engagement capability:

- Target speed 300m/s (Mach 1.0) 50-5000 m altitude, 9 km range
- Target speed 420m/s (Mach 1.4) 200-5000 m altitude, 7 km range

Right the fielding the modernization of the complex begun with the following requirements:

- Improving side visibility of the drivers, during the training for the Red Square parade showed drivers could hardly keep the vehicles aligned for the parade.
- Capability of killing targets with 500 m/s (Mach 1.6) speed
- Capability of killing receding targets up to 300 m/s (Mach 1.0).
- Improving the missile overload capability to 25G.

One of the lessons learned from the ongoing War of Attrition (between Egypt and Israel) was that Soviet SAM systems strongly needed to increase the number of ready-to-launch missiles. Therefore DF Ustinov (Minister of Defense of the Soviet Union ordered to redesign the Osa to be able to carry double amount (eight) missiles. The lead designer objected because the payload limitations of the BAZ vehicle but reply of the DF Ustinov) was short:

"This is your concern, report on the execution!"
After investigation the order Efremov called back the Minister.
"We have worked on your order about the possibility of installing eight missiles on the vehicle. Eight did not work but we could place six rockets in canisters."
DF Ustinov thought for a moment and replied: *"a black sheep is dreaming about white wool"*

Following the decision in 1973 the Osa-A and Osa-AK upgrade programs were merged to create the new 9K33M2 Osa AK variant. Following the successful state trials at the second half of 1974 it was fielded in February 1975. Export of the AKM variant started in 1980 (21 years after starting the development.)

Was a funny side effect of redesigning process of the Ellipse system. Every army air defense systems in the USSR were named after geometric shapes such as SA-6 /2K12 Kub where Kub means "cube", SA-7 / 9K32 Strela-2 where Strela means "Arrow", SA-4 / 2K11 Krug means "Circle." Because the designers of the PVO SAM systems redesigned and finished the new army air defense SAM system it was renamed to Osa using the similar naming method as PVO SAMs. This was a "gentle" reminder about who helped out the original development team.

In my opinion the until arrival of Buk-M1 (even Buk is a much more robust system on higher organization level) considering the parameters of the system Osa-AKM was the (one of) most dangerous army air defense system in the world. It was capable to carry lots of missiles none of the western SHORAD system had 6 missiles in ready to launch state. The minimal and maximal altitude of the engagement zone covered all the tactical targets in that era. The missile was enough versatile to defat or just mean very serious threat even for 4th generation fighters. The range and engagement altitude made possible to engage any aircraft with any weapons before it could launch first. Even the best air to ground missile of '80s the AGM-65D-2 had smaller usable engagement range.

(In theory F-111F could bomb with laser guided bombs and Pave Tack targeting system above the engagement zone of the Osa but F-111F had totally different types much more important targets in Europe. Using as a tanks destroyer during Operation Desert Strom was an exception and tanks were mostly stationary which is a totally different set up comparing to CAS requirements.)

The anti-radiation missile (ARM) resistance of the Osa was also good with AGM-45 Shrike was almost impossible to attack the Osa because in case of the narrow beam illumination only the AGM-45 carrier could launch the ARM. Moreover only a very short time was available to react less than 25-30 seconds considering the maximal range of the Osa. The launcher SAM could hit the AGM-45 carrier and after the successful engagement Osa could turn off its radar before the ARM get in range.

Only the appearance of the AGM-88 HARM changed dramatically the situation because HARM can use the sidelobes of the radars for guidance. Regardless of the more advanced seeker of the HARM the short guidance and illumination time is a very serious limitation for any ARM.

With adequate IADS support using the optical target tracking capability of Osa on paper it made the most deadliest threat what NATO air forces had to face it during the Cold War from the mid '70s. (Only a handful or more advanced radar guided army air defense SAMs entered in service until the end of Cold War.)

Considering the features and capabilities of the Osa it is very surprising how weak was the performance of the Osa during the Desert Storm. Until this day is no reliable and publicly available source what could cause this while even much older SAM systems were more successful than Osa. For example with one S-75M Volkhov battery successfully downed an F-15E Strike Eagle.

As usual finally are some video about the system:

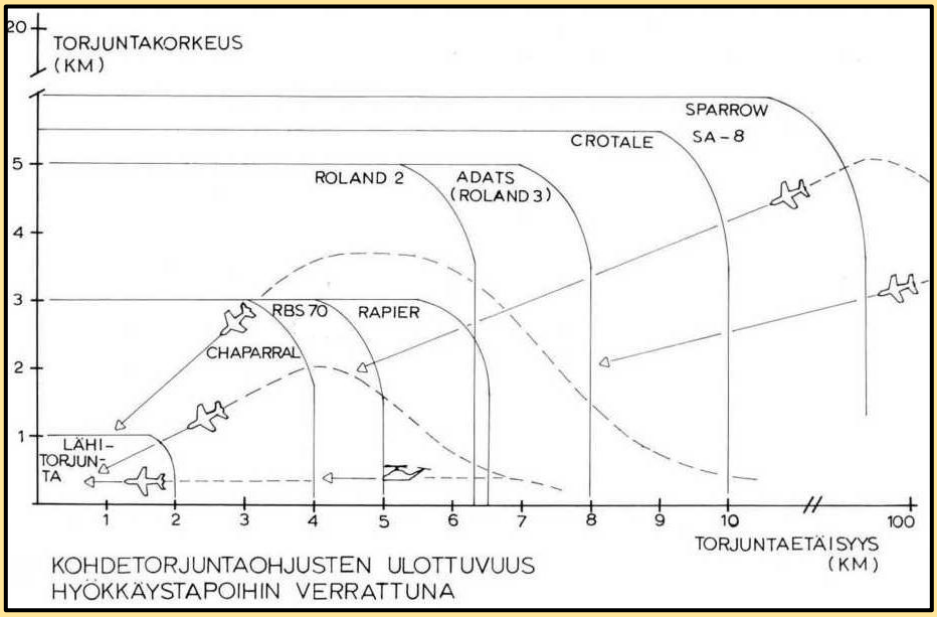
https://www.youtube.com/watch?v=QdeLa42kz_I
https://www.youtube.com/watch?v=14IhEMmItYk
http://www.ausairpower.net/APA-9K33-Osa.html

Not only the USSR and NSWP countries but the NATO and other western world nations used or still are using similar self-propelled short range SAM systems (SHORAD) but most of them have about "half size smaller" engagement range. Most of western SHOARAD system during the Cold War had 6-8 km or even less range and their maximal target altitude rarely was above 3 km.

Such SHORAD system was the joint developed German-French Roland, the English Rapier, the French Crotale[2] and post-Cold War Crotale NG, the less known ADATS[3] or the American Mauler[4] (SARH) which never entered into service. These systems typically used radio command guidance method the slight difference was mostly in the exact method of target and missile tracking.

For example the Crotale R440 instead of radio tracking used infrared sensor to guide the missile into the main lobe[5] of the target and missile tracking radar while the Osa used lots of smaller antennas. Very likely three point guidance is used similarly to SA-8. The engagement zone of the Crotale is also displayed very differently from the SA-8 because the kinematics of the missile is much weaker comparing to the Soviet SAM.

[2] *http://www.ausairpower.net/APA-HQ-7-Crotale.html*,
[3] *http://www.designation-systems.net/dusrm/m-146.html*
[4] *https://www.secretprojects.co.uk/mauler.pdf*
[5] *http://www.ausairpower.net/PLA-IADS/Crotale-IDR-1-1970-Figure-1S.jpg*



At 5, 6, 10 and 13 km distance the missile is able to perform only 27, 18, 8 and finally only 3G turn which combined with three point guidance it means against maneuvering targets the real engagement range is smaller. If the SA-8 is the bar with similar requirements the range of Crotale is only about 5 km not 10 km.

Comparing to Osa the Crotale does not have target acquisition radar on the launcher vehicle it is on another vehicle the system is less compact and unified. The SA-8 is also very unique because of its amphibious capability.

Above left is the French-German Roland on the chassis on the Marder IFV on right is the launcher vehicle of first Crotale system

Western designers many time thought differently in design. The Osa AKM has 6 missiles ready to launch while some NATO SHOARD has only 2 or 4 but with different conception. For example in case of Roland Marder SAM two missile salvo is possible then is a quick reload process (it takes less than 10 seconds) the next pair is ready to launch. The total inventory of the Roland is 10 missiles. This means the fire rate of the Osa is slightly higher up to 6 missiles but after that a much more time consuming reload is needed while the Roland remains combat capable longer because it has more and smaller missile. Some of the western SHORAD systems are on the video links below.

https://www.youtube.com/watch?v=YYtop83C6yU

https://www.youtube.com/watch?v=USh97KrOMjY

It is interesting USA participated and initiated many SHORAD and AAA developing programs for example for a while it was in the German-Roland program. USA designed the Mauler system with SARH guidance as well as the badly failed M247 Sergeant York. [6]

Despite the many efforts only the M48 Chaparral was entered in service as an interim solution which eventually was used more than 30 years and many times have been upgraded. Since the mid '90s USA does not have any SAM system between the Stinger missile based Avenger and the long range Patriot system because both MIM-23 HAWK and M48 Chaparral retired in '90s in USA. The short lived M6 Linebacker also was FIM-92 missile based system[7] and even it will be revived it [8] it would not mean a new category in range and capabilities only the platform is different from the Avenger.

NASAMS could be a mobile army air defense system but regardless the NASAMS use American AIM-120 AMRAAM missile USA uses only for defense the White House and the Pentagon in such small quantity which can be considered only anti-terrorist role. Comparing to the strongly layered army air defense USA army air defense just barely exist and USA is not exceptional. We can say the multi layered Soviet Russian army air defense is unique none of other nations of the world ever had any similar.

[6] *https://www.youtube.com/watch?v=ogDgLOJOKJs* , *https://www.youtube.com/watch?v=TanFPsRaeto*
[7] *http://www.military-today.com/missiles/m6_linebacker.htm*
[8] https://nationalinterest.org/blog/the-buzz/the-us-army-getting-ready-bring-back-the-linebacker-24146